Progress Towards a Primary Pressure Standard Based on the Dielectric Permittivity of Helium

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A novel pressure standard, based on measuring the dielectric permittivity of helium is under development by the Fluid Sciences Group at NIST. Pressure is related to the dielectric permittivity through the dielectric virial equation in which the leading coefficient is known from theory with an uncertainty of less than 1×10^{-6}. Experimentally, we have established the relationship between temperature, pressure and the dielectric permittivity of helium with a relative uncertainty of about 50×10^{-6} near 0 °C and 7 MPa using a toroidal cross-capacitor and, independently, a linear cross-capacitor to measure the dielectric permittivity. The experimental uncertainties are dominated by the measurement of the capacitance, and by the stability of the cross capacitors. We plan to improve both using novel designs for gas filled cross capacitors and better capacitance bridges. One capacitor design relies on a 64-element linear array made from tungsten carbide, while a second design uses an arrangement of 4 steel rings that eliminates end effects. A third design relies on a "star" sapphire, which serves as a very stable scaffold for the electrodes that form the cross capacitor. The performance of the 3 designs will be discussed. We have exploited our cross capacitors to measure reference values of the dielectric permittivity of the 7 gases, argon, nitrogen, oxygen, carbon dioxide, methane, ethane, and propane at 3 temperatures 0 °C, 22 °C and 50 °C.